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H04B 10/18

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H4B BK18

(56) Documents Cited
GB 2268018 A EP 0684709 A1 EP 0657754 A1

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UK CL (Edition O) H4B BK18
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(54) Chromatic dispersion compensation in wavelength division multiplexed light

(57) Wavelength division multiplexed optical signals with different wavelength dispersion are compensated for wavelength dispersion in a optical transmission line. Each multiplexed wavelength λ1 - λn is selected by band pass filters 11-1 - 11-n. The selected optical signal for each wavelength is independently compensated for the wavelength dispersion by wavelength dispersion compensation sections 12-1 - 12-n. The wavelength dispersion compensation section of each wavelength has a optical fiber having a dispersion value with polarity opposite to that of the optical transmission line. Zero dispersion is attained for each wavelength λ1 - λn as a whole, and transmission distance of wavelength division multiplexed optical signals can be extended.

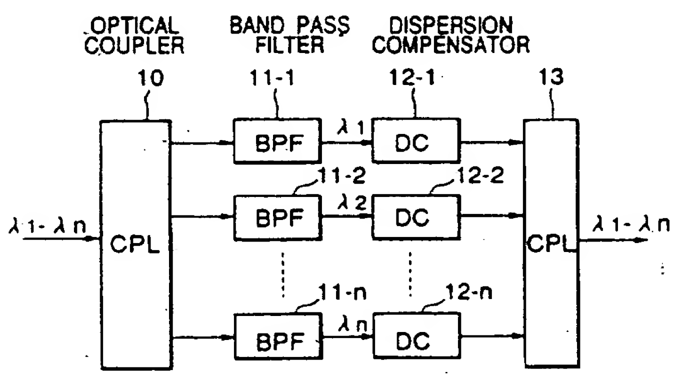

FIG.3

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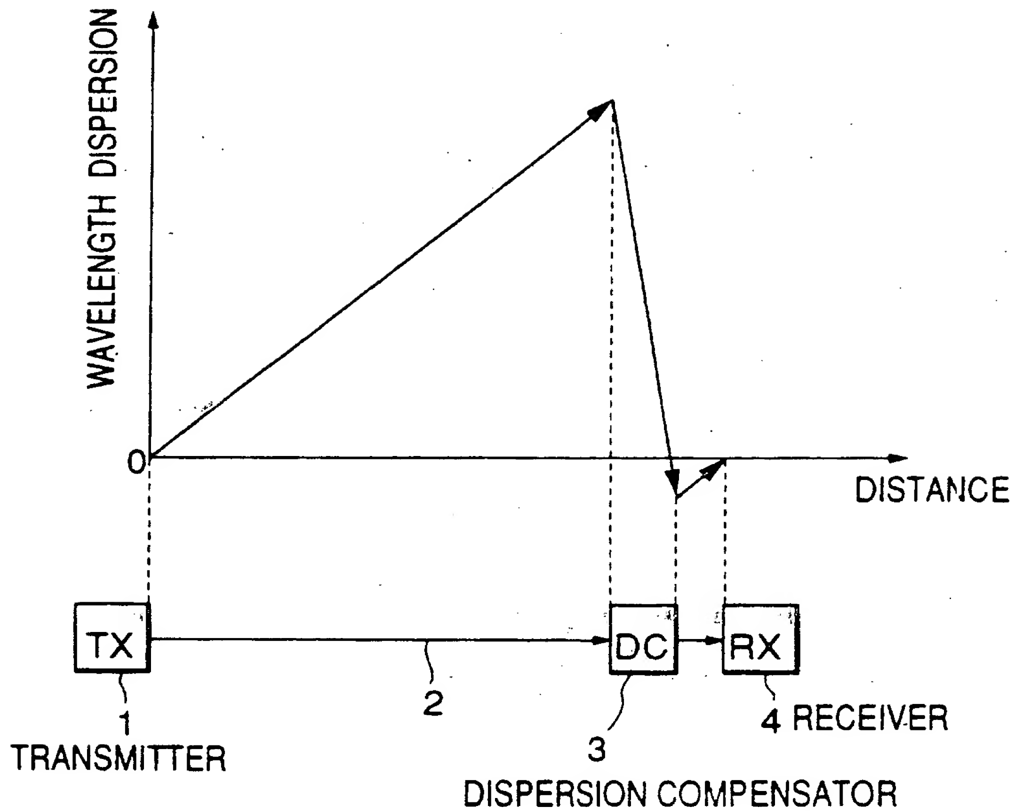


FIG.1 PRIOR ART

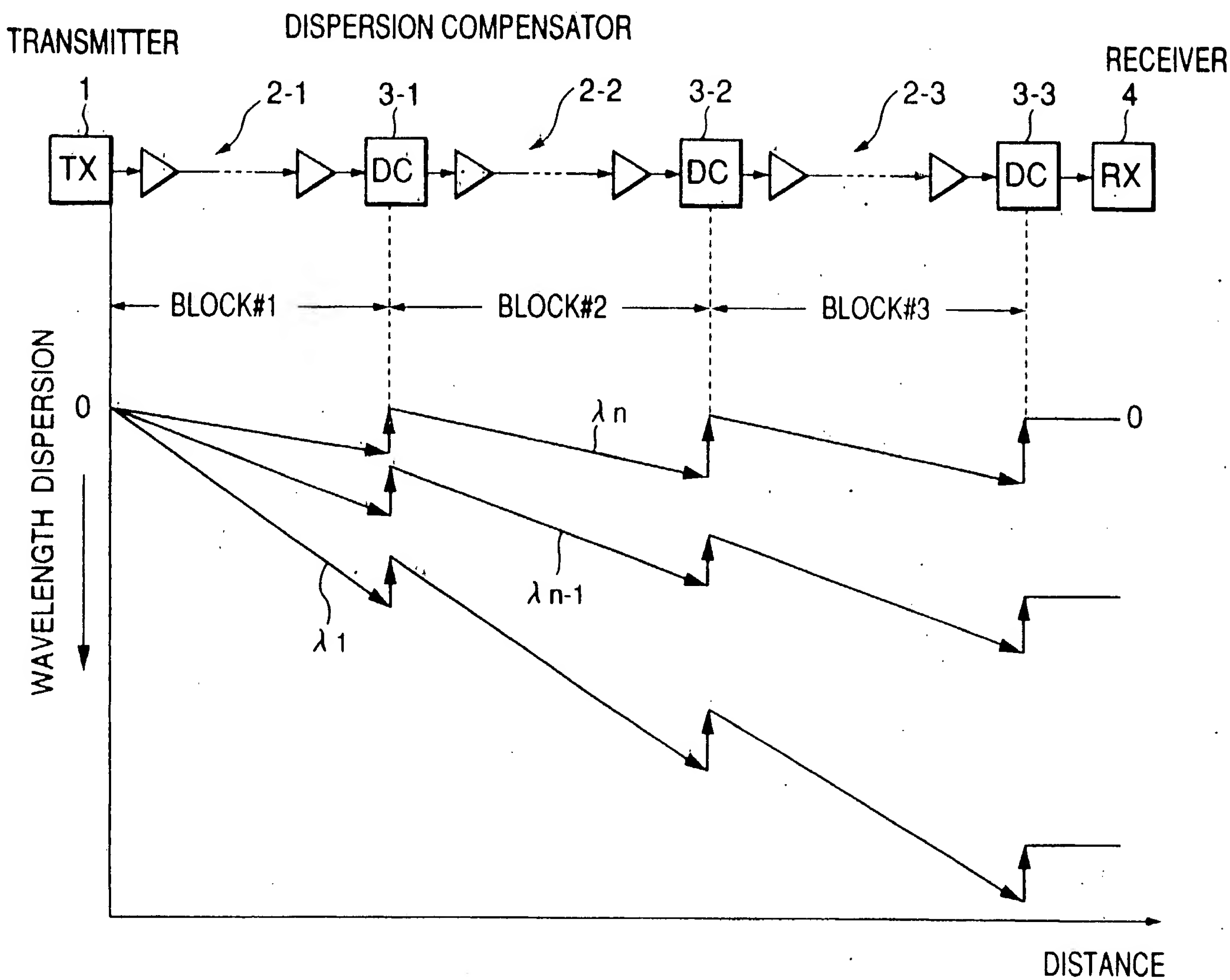
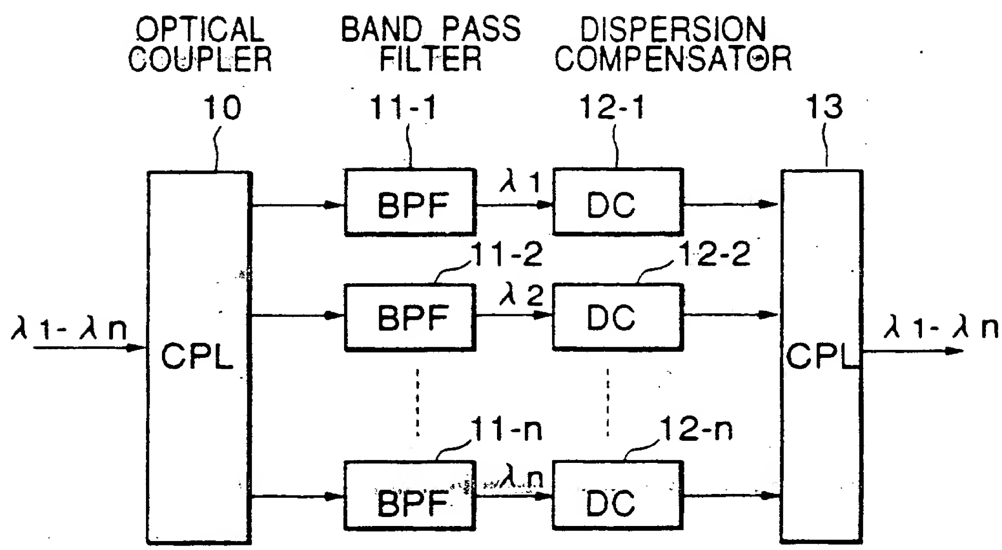


FIG.2 PRIOR ART



OPTICAL COUPLER
BAND PASS FILTER
DISPERSION COMPENSATOR
10
11-1
12-1
13
BPF
λ1
DC
11-2
12-2
BPF
λ2
DC
λ1-λn
CPL
CPL
λ1-λn
11-n
12-n
BPF
λn
DC

FIG.3

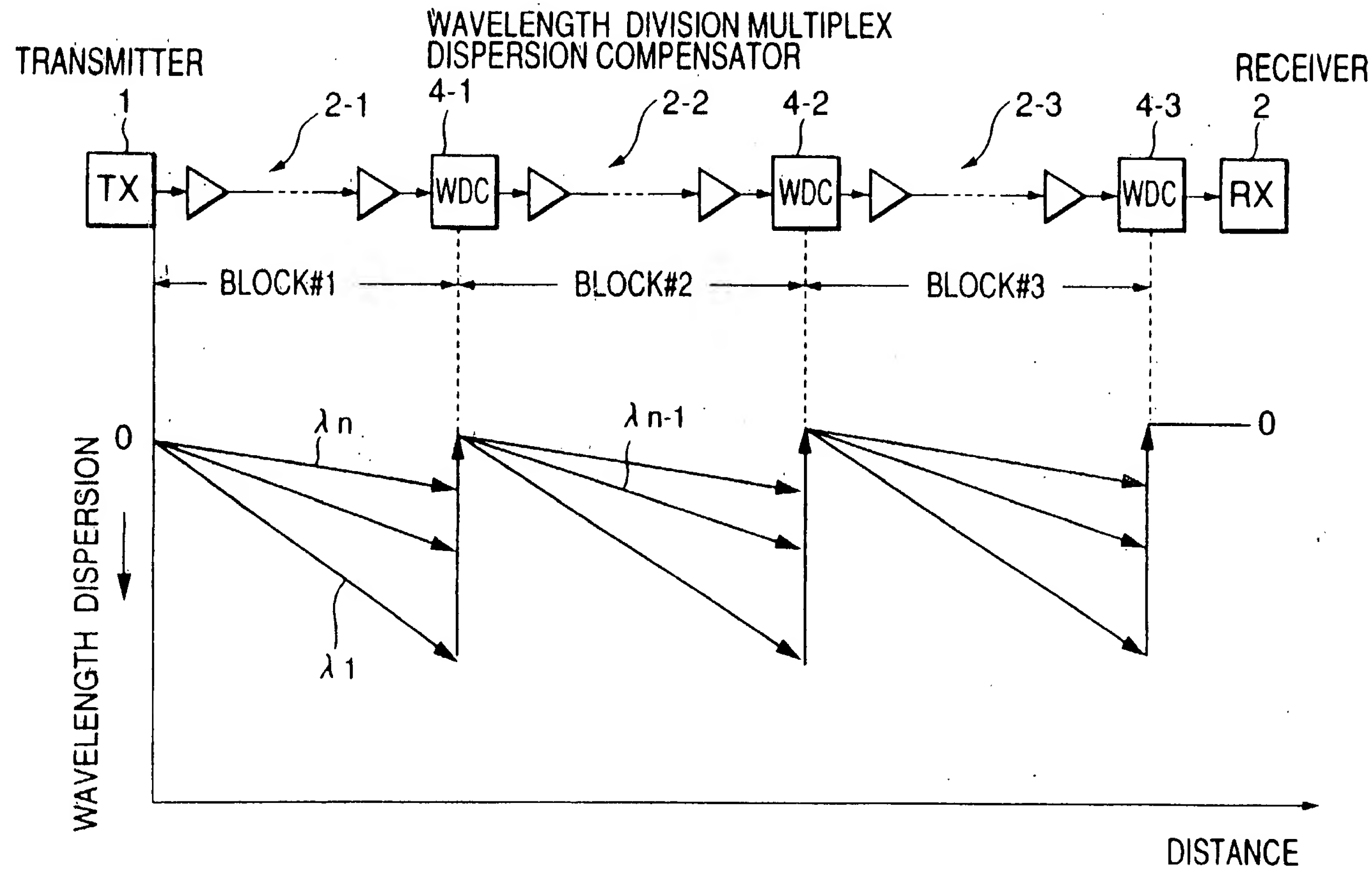

WAVELENGTH DIVISION MULTIPLEX
DISPERSION COMPENSATOR
TRANSMITTER
1
TX
2-1
4-1
WDC
2-2
4-2
WDC
2-3
4-3
WDC
RECEIVER
2
RX
BLOCK#1
BLOCK#2
BLOCK#3
0
λ n
λ n-1
λ 1
0
WAVELENGTH DISPERSION
DISTANCE

FIG.4

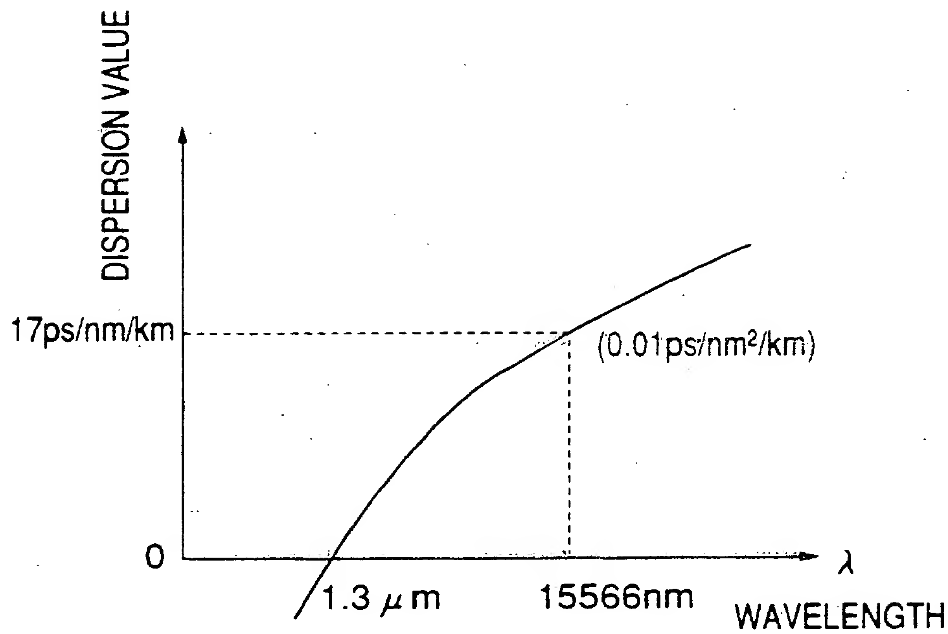

DISPERSION VALUE
17ps/nm/km
(0.01ps/nm²/km)
0
λ
1.3 μm
15566nm
WAVELENGTH

FIG.5

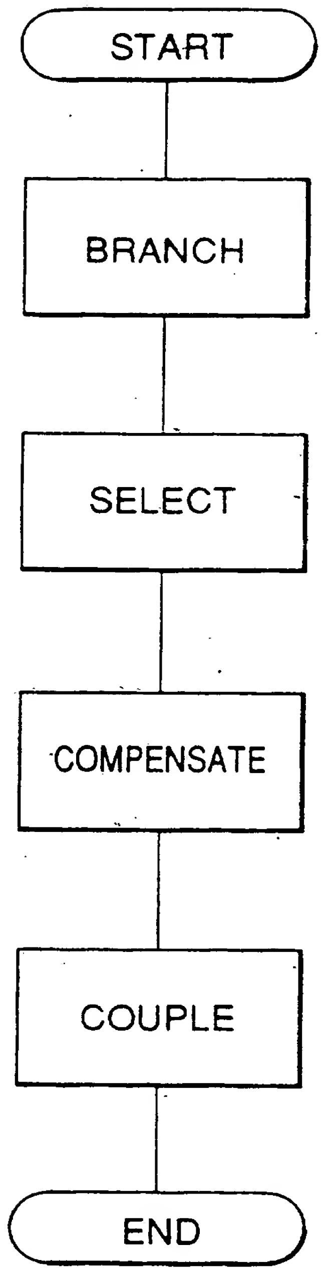


FIG.6

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AN OPTICAL TRANSMISSION LINE FOR WAVELENGTH DIVISION MULTIPLEXED OPTICAL SIGNALS

The present invention relates to an optical transmission line for wavelength division multiplexed optical signals, and, more particularly, to a wavelength dispersion compensation system for an optical transmission line in an optical wavelength division multiplex transmission repeating system which uses an optical direct amplifier.

In an optical communication system using an optical fiber as the transmission line, wavelength dispersion compensation is performed due to wavelength dispersion characteristics of the optical fiber. Japanese Laid-open Patent Application No. 62-275204 discloses technology of the wavelength dispersion compensation system. A wavelength dispersion compensator (WDC) is provided to compensate for wavelength dispersion on an optical fiber, which is an optical transmission line between a transmitter and a receiver. The wavelength dispersion compensator is arranged to compensate for wavelength dispersion by the optical transmission line so that entire wavelength dispersion from the transmitter to the receiver is made equivalent to zero. The wavelength dispersion compensator makes the entire wavelength dispersion substantially zero by using optical fiber which has a wavelength dispersion value whose polarity is opposite to that of the optical transmission line, and by controlling the length of the optical fiber.

When such conventional wavelength dispersion compensation system is applied to an optical wavelength division multiplex (WDM) transmission line, there arises the following problem. Assume that the multiplexed wavelengths are n wavelengths of λ1 - λn (n being integer of 2 or more), and that n optical signals with different wavelengths are multiplexed, transmitted and repeated over transmission lines. In such system, if the wavelength dispersion characteristics of the dispersion compensator are defined by an optical fiber optics which provides zero dispersion characteristics for an optical signal wavelength of λn, the wavelength dispersion of the other optical signals having wavelength λ1 - λ(n-1) still remains.

The conventional dispersion compensation system compensates for the wavelength dispersion of an optical signal of wavelength λn so that the dispersion becomes zero. However, this compensation is ineffective for the other optical signals of wavelength λ1 - λ(n-1).

It is, therefore, an object of at least the preferred embodiments of the present invention to provide an optical transmission line for wavelength division multiplexed optical signals which can compensate for wavelength dispersion so that the dispersion becomes substantially zero for each wavelength transmitted in the optical transmission line.

An optical transmission line for wavelength division multiplexed optical signals of the present invention comprises an optical fiber, and at least one wavelength division multiplex dispersion compensator for compensating for wavelength dispersion

of each optical signal of the wavelength division multiplexed optical signals.

Preferably, the wavelength division multiplex dispersion compensator comprises an optical coupler for making the wavelength division multiplexed optical signals branch, a plurality of band pass filters for selecting a optical signal with a predetermined wavelength from the branched wavelength division multiplexed optical signals, and a plurality of wavelength dispersion compensation sections for compensating the wavelength dispersion of the selected optical signal.

An optical signal transmitting method of the present invention comprises the steps of making wavelength division multiplexed optical signals branch, selecting an optical signal with a predetermined wavelength from the branched wavelength division multiplexed optical signals, compensating for the wavelength dispersion of the selected optical signal and coupling each compensated optical signal.

In this optical transmission line and optical signal transmitting method, there is provided an advantage that each optical signal with different wavelength dispersion in the optical transmission line can be compensated for wavelength dispersion.

Preferred features of the present invention will now be described, purely by way of example only, with reference to the accompanying drawings, in which:-

FIG.1 is a diagram illustrating an example of a conventional wavelength dispersion compensation method;

FIG.2 is a system configuration of an optical transmission line to which a conventional wavelength dispersion compensation method is applied, and its wavelength dispersion characteristics.

FIG.3 is a block diagram of an embodiment of a wavelength division multiplex compensator of the present invention.

FIG.4 is a system configuration of an optical transmission line to which the embodiment of the present invention is applied, and its wavelength dispersion characteristics.

FIG.5 is an example of characteristics of a dispersion compensation fiber in a wavelength division multiplex dispersion compensator.

FIG.6 is a flow chart which shows an optical signal transmitting method of the present invention.

To better understand the present invention, a brief reference will be made to the conventional wavelength dispersion compensation method shown in FIGs.1 and 2.

Referring to Figure 1, a wavelength dispersion compensator (DC) 3 is provided immediately before a receiver (RX) 4 to compensate for the wavelength dispersion on the optical fiber 2 which is an optical transmission line between a transmitter (TX) 1 and the receiver (RX) 4. The wavelength dispersion compensator 3 is arranged to compensate for the wavelength

dispersion by the optical transmission line 2 so that the entire wavelength dispersion from the transmitter 1 to the receiver 4 is made substantially equivalent to zero. The wavelength dispersion compensator 3 makes the entire wavelength dispersion substantially zero by using an optical fiber which has a wavelength dispersion value of a polarity opposite to that of the optical transmission line 2, and by controlling the length of the optical fiber.

FIG.2 shows such a conventional wavelength dispersion compensation system applied to an optical wavelength division multiplex (WDM) transmission line. In this case, the multiplexed wavelengths are n wavelengths of λ1 - λn (n being integer of 2 or more), and optical signals with n wavelengths are multiplexed, transmitted and repeated over transmission lines 2-1 - 2-3 (each triangle in the transmission line represents an optical amplifier). The transmission line between the transmitter 1 and the receiver 4 is divided into, for example, three blocks #1 - #3. Wavelength dispersion compensators 3-1 - 3-3 are disposed in correspondence to each block #1 - #3 so as to compensate for the wavelength dispersion of the transmission lines 2-1 - 2-3 in each block #1 - #3.

In such a system, if the wavelength dispersion characteristics of the dispersion compensators 3-1 - 3-3 are defined by an optical fiber which provides zero dispersion characteristics for an optical signal wavelength of λn, the relationship of the wavelength dispersion value to the distance for each wavelength λ1 - λn is as shown by the lower graphs in FIG.2. That is, there is a problem that the conventional dispersion compensation system

compensates for the dispersion of an optical signal having one wavelength of λn so that the dispersion becomes zero. However, this compensation is ineffective for the other optical signals having wavelengths of λ1 - λ(n-1).

FIG.3 is a block diagram of the wavelength dispersion compensator (WDC) according to an embodiment of the present invention. In FIG.3, the wavelength division multiplexed optical signals (with wavelength of λ1 - λn) inputted from an optical transmission line are branched into n by an optical coupler (CPL) 10, and input into BPFs (band pass filters) 11-1 - 11-n for selecting a wavelength. Each optical signals with wavelength of λ1 - λn selected by BPFs 11-1 - 11-n is input for each wavelength into the wavelength dispersion compensation sections 12-1 - 12-n for wavelength dispersion compensation. Each optical signal after the compensation is coupled again by the optical coupler 13, and introduced into the optical transmission line. The above-described elements constitute a wavelength division multiplex dispersion compensator (WDC).

FIG.4 shows a system block diagram and a wavelength dispersion characteristic diagram of the optical transmission line using the wavelength dispersion compensator of FIG.3. The components similar to those of FIG.1 are designated by like references. The optical transmission line from the transmitter 1 to the receiver 2 is divided into three blocks of #1 - #3 in this example. The wavelength division multiplex dispersion compensators (WDCs) 4-1 - 4-3 of FIG.3 are disposed at the end of each block, respectively.

With such arrangement, the optical signals with four wavelength $\lambda 1$ - λn are considered, with $n = 4$. Then, it is assumed that $\lambda 1$ = 1,556 nm, $\lambda 2$ = 1,557 nm, $\lambda 3$ = 1,558 nm, and $\lambda 4$ = 1,559 nm, and that each optical fiber 2-1 - 2-3 of the transmission line is a so-called dispersion shifted fiber (DSF) with a zero dispersion wavelength of 1,563 nm and dispersion inclination factor of about 0.07 ps/nm²/km. Now, when the transmission distance of each block #1 - #3 is 800 km, total dispersion value of each wavelength is:

$$D1\ (\lambda 1) = -392\ \text{ps/nm} \quad \ldots . \quad (1)$$

$$D2\ (\lambda 2) = -336\ \text{ps/nm} \quad \ldots . \quad (2)$$

$$D3\ (\lambda 3) = -280\ \text{ps/nm} \quad \ldots . \quad (3)$$

$$D4\ (\lambda 4) = -224\ \text{ps/nm} \quad \ldots . \quad (4).$$

Here, the formula for calculating the total dispersion values D1 - D4 at each wavelength is represented by

$$D = (0.07\ \text{ps/nm}^2/\text{km}) \times (\lambda - 1{,}563\ \text{nm}) \times 800\ \text{km}.$$

The optical transmission lines 2-1 - 2-3 have a negative (-) dispersion value for each wavelength $\lambda 1$ - $\lambda 4$.

The total dispersion values D1 - D4 for these wavelengths $\lambda 1$ - $\lambda 4$ are compensated in dispersion compensation sections 12-1 - 12-4 for each wavelength for each block as shown in FIG.3 by the wavelength division multiplex dispersion compensators (WDCs) 4-1 - 4-3, each WDC having the structure shown in, for example, Fig. 3. Then, the wavelength dispersion is made zero, or substantially zero, at the end of each block #1 - #3.

To this end, a zero dispersion fiber of 1.3 μm, for example, is used as the dispersion compensation sections 12-1 -

12-4. The 1.3 μm zero dispersion fiber has the dispersion inclination factor 0.01/ps/nm^2/km at wavelength $\lambda 1$ = 1,556 nm as shown in FIG.5 which depicts a graph of its wavelength dispersion characteristics.

The dispersion values per km for each wavelength of the dispersion compensation fiber are:

17.00 ps/nm/km (at $\lambda 1$ = 1,556 nm)

17.01 ps/nm/km (at $\lambda 2$ = 1,557 nm)

17.02 ps/nm/km (at $\lambda 3$ = 1,558 nm)

17.03 ps/nm/km (at $\lambda 4$ = 1,559 nm).

Therefore, to compensate for each of the dispersion values by a transmission line of 800 km, as expressed by equations (1) - (4) so as to equivalently attain substantially zero dispersion as a whole in each block, it is effective to select the following length for each dispersion compensation fiber:

23.1 km (at $\lambda 1$ = 1,556 nm)

19.8 km (at $\lambda 2$ = 1,557 nm)

16.5 km (at $\lambda 3$ = 1,558 nm)

13.2 km (at $\lambda 4$ = 1,559 nm).

Then, the dispersion compensation value for each wavelength is:

$$D1' = +392 \text{ ps/nm} \quad \ldots. \quad (5)$$

$$D2' = +336 \text{ ps/nm} \quad \ldots. \quad (6)$$

$$D3' = +280 \text{ ps/nm} \quad \ldots. \quad (7)$$

$$D4' = +224 \text{ ps/nm} \quad \ldots. \quad (8).$$

The polarity symbol is reversed to that of each dispersion value in equations (1) - (4) so that the dispersion compensation can be attained.

Each dispersion compensation fiber is wound around a cable drum to align at one position. Then, all wavelength dispersion by the transmission lines 2-1 - 2-3 can be compensated at one point at each WDC 4-1 - 4-3, as shown by the graph in FIG.4.

The optical transmission line can have an optical fiber with a positive dispersion value for each wavelength. Then the wavelength dispersion compensation section has a transmission channel which may be, for example, an optical fiber with a negative dispersion value so that the dispersion compensation can be attained.

Furthermore, the optical transmission line and the wavelength dispersion compensation section can have an optical fiber with a positive dispersion value for part of the wavelengths and the negative dispersion value for the other wavelengths.

FIG.6 shows an embodiment of an optical signal transmitting method of the invention. At first, the wavelength division multiplexed optical signals are branched. The optical signal with predetermined wavelength is selected from each of the plurality of branched signals. Each selected optical signals is compensated for a wavelength dispersion and coupled together.

As described above, the present invention is arranged to perform the wavelength dispersion compensation for each

wavelength division multiplexed optical signal wavelength. There is provided an advantage in that all of the optical signal wavelengths with different wavelength dispersion characteristics can be simultaneously and completely compensated for wavelength dispersion, and the transmission distance can be extended.

While the present invention has been described in connection with certain preferred embodiments, it is to be understood that the subject matter encompassed by the present invention is not limited to those specific embodiments. On the contrary, it is intended to include all alternatives, modifications and equivalents as can be included within the scope of the following claims.

Each feature disclosed in this specification (which term includes the claims) and/or shown in the drawings may be incorporated in the invention independently of other disclosed and/or illustrated features.

The text of the abstract filed herewith is repeated here as part of the specification.

Wavelength division multiplexed optical signals with different wavelength dispersion are compensated for wavelength dispersion in a optical transmission line. Each multiplexed wavelength $\lambda 1$ - λn is selected by band pass filters 11-1 - 11-n. The selected optical signal for each wavelength is independently compensated for the wavelength dispersion by wavelength dispersion compensation sections 12-1 - 12-n. The wavelength dispersion compensation section of each wavelength has a optical fiber having a dispersion value with polarity opposite to that of the optical transmission line. Zero dispersion is attained for each wavelength $\lambda 1$ - λn as a whole, and transmission distance of wavelength division multiplexed optical signals can be extended.

CLAIMS

1. An optical transmission line for wavelength division multiplexed optical signals comprising:

an optical fiber;

at least one wavelength division multiplex dispersion compensator for compensating for a wavelength dispersion of each optical signal in the wavelength division multiplexed optical signals.

2. The optical transmission line for wavelength division multiplexed optical signals according to Claim 1, wherein the wavelength division multiplex dispersion compensator comprises:

an optical coupler for branching the wavelength division multiplexed optical signals;

a plurality of band pass filters each band pass filter being adapted to select an optical signal of a predetermined wavelength from the branched wavelength division multiplexed optical signals; and

a plurality of wavelength dispersion compensation sections, each of which is connected to a corresponding one of said plurality of band pass filters for compensating for the wavelength dispersion of the selected optical signal.

3. The optical transmission line for wavelength division multiplexed optical signals according to Claim 2, further comprising a coupler connected to an output of each of said plurality of wavelength dispersion compensation sections for coupling compensated optical signals.

4. The optical transmission line for wavelength division multiplexed optical signals according to Claim 2 or 3, wherein each of said plurality of wavelength dispersion compensation sections comprises an optical fiber having a dispersion value of a polarity opposite to that of the optical transmission line.

5. The optical transmission line for wavelength division multiplexed optical signals according to Claim 4, wherein the optical fiber of the optical transmission line has negative dispersion values for each wavelength of optical signals, and wherein the optical fiber of each of said plurality of wavelength dispersion compensation sections has a positive dispersion value.

6. The optical transmission line for wavelength division multiplexed optical signals according to Claim 4 or 5, wherein each of the optical fibers of each of the plurality of wavelength dispersion compensation sections has a predetermined length so that a sum of dispersion values attributable to the optical transmission line and dispersion values attributed to the optical fiber of the wavelength dispersion compensation section becomes substantially zero.

7. A method of transmitting optical signals through an optical fiber transmission line, said method comprising the steps of:

branching wavelength division multiplexed optical signals into a plurality of branched wavelength division multiplexed optical signals;

selecting an optical signal with a predetermined wavelength from each of the plurality of branched wavelength division multiplexed optical signals;

compensating for a wavelength dispersion of each of the selected optical signals; and

coupling each of the compensated optical signals.

8. The optical signals transmitting method according to Claim 7, wherein said selecting step is carried out by band pass filtering each of said plurality of branched wavelength division multiplexed optical signals.

9. The optical signals method according to Claim 7 or 8, wherein said compensating step is carried out by transmitting each of the selected optical signals through a corresponding transmission channel of a plurality of transmission channels, each corresponding transmission channel having a dispersion value polarity which is opposite to that of said optical fiber transmission line.

10. The optical signals transmitting method according to Claim 9, wherein said plurality of transmission channels are selected such that, for each wavelength of the optical signals, a sum of dispersion values attributable to the optical fiber transmission line and dispersion values attributable to said corresponding transmission channel is substantially zero.

11. The optical signals transmitting method according to Claim 10, wherein said selection step is carried out by controlling a length of each of said plurality of transmission channels.

12. The optical signals transmitting according to Claim 10 or 11, wherein optical fibers are selected as said plurality of transmission channels.

13. An optical transmission line for wavelength division multiplexed optical signals substantially as herein described with reference to and as shown in Figure 3 of the accompanying drawings.

14. A method of transmitting optical signals through an optical fiber transmission line substantially as herein described with reference to Figure 6 of the accompanying drawings.

The Patent Office

Application No:	GB 9700424.6	**Examiner:**	Stephen Brown
Claims searched:	1-14	**Date of search:**	17 March 1997

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): H4B: BK18

Int Cl (Ed.6): H04B: 10/18

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
Y	GB 2 268 018 A	(Denwa) See figure 1,	5
X, Y	EP 0 684 709 A1	(AT&T) See figure 8, column 1, lines 33-41, and column 5, lines 6-23,	X: 1 Y: 4-6, 9-12,
X, Y	EP 0 657 754 A1	(AT&T) See figure 8, column 4, line 53, to column 5, line 18.	X: 1-3, 7, 8 Y: 4-6, 9-12

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		